3. The nitrogen and sulphur constituents of petroleum could only have been formed directly from or through the agency of animal organic matter.

There is an attractive field for the chemical geologist to study, more intimately than has ever been done, the occurrence of petroleum in connection with its composition.

CLEVELAND, O.

THE FORWARD MOVEMENT IN PLANT-BREEDING.

BY L. H. BAILEY.

(Read April 2, 1903.)

The first specific interest in cultivated plants was in the gross kinds or species. As the contact with plants became more intimate, various indefinite form-groups were recognized within the limits of the species. Gradually, with the intensifying of domestication and cultivation, very particular groups appeared and were recognized. These smaller groups came finally to be designated by names, and the idea of the definite and homogeneous cultural variety came into existence. The variety-conception is really a late one in the development of the human race. It is practically only within the past two centuries that cultivated varieties of plants have been recognized as being worthy of receiving designative names. It is within this period, also, that most of the great breeds of animals have been defined and separately named.

All this measures the increasing intimacy of our contact with domesticated plants and animals. It is a record of our progress. The peoples that are most advanced in the cultivation of any plant are the ones that have the most named varieties of that plant. In Japan, to this day, the plums pass under ill-defined class-names. We have introduced these classes, have sorted out the particular forms that promise to be of value to us and have given them specific American names. Not long ago a native professor in Japan wrote me asking for cions of these plums, in order that he might introduce Japanese plums into Japan. The Russian apples are designated to some extent by class-names; in fact, it was not until the appearance of Regel's work, about a generation ago, that Russian pomology may be said to have been born. What constitutes a variety is increasingly more difficult to define, because we are constantly differentiating on smaller points. The growth of the variety-conception is really the growth of the power of analysis.

The earlier recognized varieties seem to have come into existence unchallenged. There is very little record of inquiry as to how or why or even where they originated. That is, the quest of the origin arose long after the recognition of the variety as a variety. Even after inquisitive search into origins had begun there was little effort to produce these varieties. The describing of varieties and the search into their histories was a special work of the nineteenth century. One has only to consult such American works as Downing's *Fruits and Fruit Trees of America* and Burr's *Field and Garden Vegetables of America*, to see how carefully and methodically the descriptions and synonymy of the varieties were worked out. These are types of excellent pieces of editorial and formal systematic work.

There have been isolated efforts at producing varieties for many years. These efforts began before the time of the general discussion of organic evolution. In fact, it was on such experiments that Darwin drew heavily in some of his most important writings. Roughly speaking, however, the conception that the kinds of plants can be definitely modified and varied by man is a product of the last half century. We now believe that there is such a possibility as plant-breeding. It is really a more modern conception, so far as its general acceptance is concerned, than animal-breeding. But both animal-breeding and plant-breeding are the results of a new attitude toward the forms of life—a conviction that the very structure, habits and attributes are amenable to change and control by man. This is really one of the great new attitudes of the modern world.

Formerly, and even up to the present time, the variety has been taken as the unit for plant-breeding work, as it has been for descriptive and classificatory work. Whether we believed it or not, we have accepted it as a fairly definite thing or entity. Yet, what is a variety? Only the ideal of one man or a set of men. Custom may define its boundaries, but in fact it has no boundaries. At best, a variety is only an assemblage of forms that agree rather more than they differ: and any one of these forms may, with equal propriety, be called another variety. Shall we continue to consider the variety as a unit or basis from which we are to breed for the purpose of producing other varieties? Or shall we still further refine our ideals and find that the variety-conception is really only a mark of an imperfect and superficial development of an immature age?

Now, plant-breeding is worthy of the name only as it sets definite ideals and is able to attain them. Merely to produce new things is of no merit: that was done long before man was evolved. A child can "produce" a new variety, but it may learn nothing and contribute nothing in producing it. I have myself produced 1500 new kinds of pumpkins and squashes, but I had no idea what I was to produce, the world is no better for my having produced them, and I am no wiser (except in experience) than I was before. In many "new" things that are produced, there may be dispute as to whether they are new and as to whether they are distinct enough to be named and therefore to be ranked as varieties at all. This is not science, nor even breeding: it is playing and guessing. What does the world care whether John Jones produces "Jones' Giant Beardless wheat"? But it does care if he produces a wheat having a half of one per cent. more protein. We must give up the production of mere "varieties"; we must breed for certain definite attributes that will make the new generations of plants more efficient for certain purposes: this is the new outlook in plant-breeding.

Happily, we are not without abundant accomplishment in this new field. The last ten years has seen a remarkable specialization in the producing of plants that are adapted to particular needs. The days of merely crossing and sowing the seeds to see what will turn up are already past with those who are engaged seriously in the work. The old method was hit-and-miss and the result was to take what good luck put in your way: the new method proceeds definitely and directly and the result is the necessary outcome of the line of effort. The crux of the new ideal is efficiency in one particular attribute in the product of the breeding. These attributes are measurable: the kind of results are foreseen in the plan, or are predictable.

All these remarks are typically illustrated in the experiments with corn-breeding conducted in Illinois. It is significant to note what are the reasons for breeding new corns, as stated by Professor Hopkins in Bulletin 82 of the Illinois Experiment Station:

"In its own publication a large commercial concern, which uses enormous quantities of corn, makes the following statements:

"'A bushel of ordinary corn, weighing fifty-six pounds, contains about four and one-half pounds of germ, thirty-six pounds of dry starch, seven pounds of gluten, and five pounds of bran or hull, the balance in weight being made up of water, soluble matter, etc. The value of the germ lies in the fact that it contains over forty per cent. of corn oil, worth, say, five cents per pound, while the starch is worth one and one-half cents, the gluten one cent, and the hull about one-half cent per pound.

"'It can readily be seen that a variety of corn containing, say, one pound more oil per bushel would be in large demand.

"'Farmers throughout the country do well to communicate with their respective agricultural experiment stations and secure their co-operation along these lines.'

"These are statements and suggestions which should, and do, attract the attention of experiment station men. They are made by the Glucose Sugar Refining Company of Chicago, a company which purchases and uses, in its six factories, about fifty million bushels of corn annually. According to these statements, if the oil of corn could be increased one pound per bushel, the actual value of the corn for glucose factories would be increased five cents per bushel; and the president of the Glucose Sugar Refining Company has personally assured the writer that his company would be glad to pay a higher price for high oil corn whenever it can be furnished in large quantities. The increase of five cents per bushel on fifty million bushels would add $2,500,000 to the value of the corn purchased by this one company each year. The glucose factories are now extracting the oil from all the corn they use and are unable to supply the market demand for corn oil. On the other hand, to these manufacturers protein is a cheap by-product and consequently they want less protein in corn.

"Corn with a lower oil content is desired as a feed for bacon hogs, especially for our export trade, very extensive and thorough investigations conducted in Germany and Canada having proved conclusively that ordinary corn contains too much oil for the production of the hard firm bacon which is demanded in the markets of Great Britain and Continental Europe."

It is very interesting to note that this does not mention the improvement of Leaming's White, or Jones' Yellow Dent, or any other named variety of corn, nor does it propose that any new variety shall be created. It suggests what may be done with any variety of corn. The experiments in Illinois demonstrate that "the yield of corn can be increased, and the chemical composition of the kernel can be changed as may be desired, either to increase or to decrease the protein, the oil, or the starch."

The breeding of the corn proceeds along two general lines—for physical perfection and for chemical perfection. Selection for physical merit proceeds as follows, to quote again from Professor Hopkins: "The most perfect ears obtainable of the variety of corn which it is desired to breed should be selected. These ears should conform to the desirable standards of this variety and should possess the principal properties which belong to perfect ears of corn, so far as they are known and as completely as it is possible to secure them. These physical characteristics and properties include the length, circumference, and shape of the ear and of the cob; the number of rows of kernels and the number of kernels in the row; the weight and color of the grain and of the cob; and the size and shape of the kernels. In making this selection the breeder may have in his mind a perfect ear of corn and make the physical selection of seed ears by simple inspection, or he may make absolute counts and measurements and reduce the physical selection almost to an exact or mathematical basis."

The selection for chemical content is made on two bases—on the general gross structure of the corn kernel as determined by "mechanical examination," and on chemical analysis of the kernel.

Chemical examination by means of mechanical examination is as follows:

"The selection of seed ears for improved chemical composition by mechanical examination of the kernels is not only of much assistance to the chemist in enabling him to reduce greatly the chemical work involved in seed corn selection, but it is of the greatest practical value to the ordinary seed corn grower who is trying to improve his seed corn with very limited service, if any, from the analytical chemist. This chemical selection of seed ears by mechanical examination, as well as by chemical analysis (which is described below), is based upon two facts:

"1. That the ear of corn is approximately uniform throughout in the chemical composition of its kernels.

"2. That there is a wide variation in the chemical composition of different ears, even of the same variety of corn. These two facts are well illustrated in Table 1.

TABLE I. PROTEIN IN SINGLE KERNELS.

	Ear A, protein, per cent.	*Ear B, protein, per cent.*	*Ear C, protein, per cent.*	*Ear D, protein, per cent.*
Kernel No. 1	12.46	11.53	7.45	8.72
" " 2	12.54	12.32	7.54	8.41
" " 3	12.44	12.19	7.69	8.73
" " 4	12.50	12.54	7.47	8.31
" " 5	12.30	12.14	7.74	9.02
" " 6	12.49	12.95	8.70	8.76
" " 7	12.50	12.84	8.46	8.89
" " 8	12.14	[1]	8.69	9.02
" " 9	12.14	12.04	8.86	8.96
" " 10	12.71	12.75	8.10	8.89

"It will be observed that while there are, of course, small differences among the different kernels of the same ear, yet each ear has an individuality as a whole, the difference in composition between different ears being much more marked than between different kernels of the same ear.

"The uniformity of the individual ear makes it possible to estimate or to determine the composition of the corn by the examination or analysis of a few kernels. The remainder of the kernels on the ear may then be planted if desired. The wide variation in the composition between different ears furnishes a starting-point for the selection of seed in any of the several different lines of desired improvement.

"The methods of making a chemical selection of ears of seed corn by a simple mechanical examination of the kernels is based upon the fact that the kernel of corn is not homogeneous in structure, but consists of several distinct and readily observable parts of markedly different chemical composition (see illustrations). Aside from the hull which surrounds the kernel, there are three principal parts in a grain of corn:

"1. The darker colored and rather hard and horny layer lying next to the hull, principally in the edges and toward the tip end of the kernel, where it is about three millimeters, or one-eighth of an inch, in thickness.

[1] Determination lost by accident.

"2. The white, starchy-appearing part occupying the crown end of the kernel and usually also immediately surrounding, or partially surrounding, the germ.

"3. The germ itself which occupies the central part of the kernel toward the tip end.

"These different parts of the corn kernel can be readily recognized by merely dissecting a single kernel with a pocket-knife, and it may be added that this is the only instrument needed by anybody in making a chemical selection of seed corn by mechanical examination.

"The horny layer, which usually constitutes about sixty-five per cent. of the corn kernel, contains a large proportion of the total protein in the kernel.

"The white, starchy part constitutes about twenty per cent. of the whole kernel, and contains a small proportion of the total protein. The germ constitutes only about ten per cent. of the corn kernel, but while it is rich in protein, it also contains more than eighty-five per cent. of the total oil content of the whole kernel, the remainder of the oil being distributed in all the other parts.

"By keeping in mind that the horny layer is large in proportion, and also quite rich in protein, and that the germ, although rather small in proportion, is very rich in protein, so that these two parts contain a very large proportion of the total protein in the corn kernel, it will readily be seen that by selecting ears whose kernels contain more than the average proportion of germ and horny layer, we are really selecting ears which are above the average in their protein content. As a matter of fact, the method is even more simple than this, because the white, starchy part is approximately the complement of, and varies inversely as, the sum of the other constituents; and to pick out seed corn of high protein content it is only necessary to select those ears whose kernels show a relatively small proportion of the white, starchy part surrounding the germ.

"As more than eighty-five per cent. of the oil in the kernel is contained in the germ, it follows that ears of corn are relatively high or low in their oil content according as their kernels have a larger or smaller proportion of germ.

"In selecting seed corn by chemical analysis, we remove from the individual ear two adjacent rows of kernels as a representative sample. This sample is ground and analyzed as completely as may be necessary to enable us to decide whether the ear is suitable for seed for the particular kind of corn which it is desired to breed. Dry matter is always determined in order to reduce all other determinations to the strictly uniform and comparable water-free basis. If, for example, we desire to change only the protein content, then protein is determined. If we are breeding to change both the protein and the oil, then determinations of both of these constituents must be made."

Any careful farmer can make such examinations as these. The relative abundance of one or the other of the three areas in the kernel will indicate what ears should be chosen for seed. Professor Hopkins proposes a system of field trials in which one ear furnishes plants for one row, thereby allowing the operator to see and measure the individuality of each ear. By choosing ears that most nearly approach the ideal, and then by continued selection year by year, the desired result is to be secured and maintained.

It is impossible to overestimate the value of any concerted corn-breeding work of this general type. The grain alone of the corn crop is worth about one billion dollars annually. It is no doubt possible to increase this efficiency by more than one per cent.

An interesting cognate inquiry to this direct breeding work is the study of the commercial grades of grains. It is a most singular fact that the dealer's "grades" are of a very different kind from the farmer's "varieties." In the great markets, for example, corn is sold as "Yellow No. 1," "Yellow No. 2," "Yellow No. 3." Any yellow corn may be thrown into these grades. What constitutes a grade is essentially a judgment on the part of every dealer. It so happens that the grade tends to deteriorate as the grain reaches the seaboard, for the tendency of each dealer is to mix with the better grades just as much of an inferior grade as will allow the carload or cargo to pass the inspector's examination. The result is that the grain is likely to be condemned or criticised when it reaches Liverpool. Complaints having come to the Government, the United States Department of Agriculture has undertaken to determine how far the grades of grain can be reduced to indisputable instrumental measurement. This work is now in the hands of Mr. Scofield, in the Division of Botany. The result is likely to be a closer defining of what a grade is; and this point once determined, the producer will make an effort to grow such grain as will grade to No. 1, and thereby reach the extra price. Eventually the efficiency points of the grower and the commercial grades of the dealer ought nearly or quite to coincide. There should come a time when corn is sold on its inherent merits, as, for example, on its starch content. This corn would not then be graded 1, 2 and 3 on its starch content, because that content would be assured in the entire product; but the Grade 1 would mean prime physical condition, and the lower grades inferior physical condition. Eventually something like varietal names may be attached to those kinds of corns that, for example, grade fifteen per cent. protein. The name would be a guarantee of the approximate content, as it now is in a commercial fertilizer.

Closely allied to the corn-breeding work of Illinois (which is carried on by the Experiment Station and also by a commercial firm organized for that purpose) is the wheat-breeding and flax-breeding work in Minnesota under the direction of Professor Hays. Mr. Hays' aim has been chiefly to increase productiveness. The following sketch is made from his notes:

"Here are three examples of increased efficiency produced at the Minnesota Experiment Station in co-operation with the U. S. Bureau of Plant Industry.

"Minn. No. 163 wheat was bred by selection from Fife parentage. During three years' comparison in field tests at University Farm, near Minneapolis, it averaged 2.7 bushels gain per acre, or eleven per cent., better than its parent variety, as shown by the following table:

Minn. No. 163	28.5	bushels.
Fife parent	25.8	"
Increase	2.7	"

"In 1899, this wheat was sold to one hundred farmers, thirty-eight of whom made the comparison between this and their common wheats in a manner fair to both. The following table shows the average increased yield to have been 1.4 bushels per acre, or eight per cent.:

Minn. No. 163, average yield	18.1	bushels.
Common wheats, average yield	16.7	"
	1.4	"

"Minn. No. 169 wheat was bred by selection from a Blue Stem foundation. During the first four years that it was in our field tests it averaged 4.9 bushels more than the parent wheat, as displayed by the following table of average yields, showing an increase over its parent variety of more than twenty per cent.:

Minn. No. 169	28.5	bushels.
Minn. No. 51	23.6	"
Gain	4.9	"

"In 1902, this wheat was sent in four-bushel lots, at $1.50 per bushel, to three hundred and seventy-five farmers. Eighty-nine reports gave comparisons that were fair both to the new and old wheats, and there were obtained the following average yields, showing an increase over the common wheats of the entire State of eighteen per cent. If this increase could be applied to one-tenth of the area of the wheat crop in Minnesota, the increased yield would be worth over a million dollars:

Minn. No. 169	21.5	bushels.
Common wheats	18.2	"
Increase	3.3	"

"The third example is even more pronounced. Seven years ago Prof. Hays chose seven samples of the common Minnesota and Dakota flax, and made by selection many new types for the production of seed, and numerous other types especially for production of fibre. The following table gives the general results:

	Yield of grain.	*Yield of straw.*	*Height in inches.*
Av. of 4 best varieties selected for seed	17.8	1.40	23
Av. of 4 best varieties selected for fibre	10.5	1.76	35
Av. of 4 best common varieties (from outside sources)	11.9	1.52	24
	5.9	.24	....

"Here in field trials, in 1902, the increased yield per acre of the new varieties bred for seed is forty-nine per cent.; and the increased height of the new varieties bred for fibre is forty-six per cent. more than the common flax."

"We have developed statistical methods," Professor Hays writes, "of dealing with such plants as wheat, alfalfa, corn, and, in fact, nearly all of the field crops where it is necessary or very advantageous to grow or plant in a hill, that selections may be made and the breeding powers of parent plants measured. The general features of this statistical work may be stated as follows: Every acquisition or newly-bred variety receives a number written thus, 'Minn. No. 13 corn,' for example. It is also botanically described and the facts concerning its history, name, description, etc., entered in our *Minnesota Number Book.* If the newly-secured variety is an exceptionally promising one it is put into field tests, but ordinarily in the preliminary garden test the first year. Promising acquisitions and promising newly-bred hybrid stocks are entered in the nursery, where their breeding by rigid selection is begun, and large numbers of plants are grown, one in each hill, giving each plant the same space and opportunities as each other plant. By processes of elimination, the few best performers are secured. The next year we plant a large number of the progeny of each of these superior mother-plants. The average yield, height and other measures are taken of the progeny of each mother-plant. These tests of the breeding values of the mother-plants are continued two and sometimes three years. Seeds from parent plants producing the best average progeny are used alone or in mixtures of close-pollinated species, and in mixtures in open pollinated species as the foundation of new varieties. These are tested in the field with the parent and other best standard varieties for three years. Any introduced or newly-bred variety which is an especially good yielder of value per acre is sent to the co-operating State Experiment Stations in surrounding States and to our substations, and its quantity is rapidly increased. Any variety that is specially promising after being tried for, say, two years at several stations is increased to sufficient quantity to sell to a number of farmers in each county in the State. This seed, backed by all the force of pedigree that we can command, is sold at a high price, so as to make the seed business profitable, and men are induced to raise it and sell large quantities at a price which will yield them a profit. In this way our first new wheat will be planted on hundreds of thousands of acres this year, and other new things are being widely disseminated."

A most gratifying augury of this coming type of effort is to be found in the work of the Plant-Breeding Laboratory of the national Department of Agriculture. This is an organization effected for the purpose of producing types or kinds of plants that shall meet particular requirements. Its work is now proceeding with many groups of plants, but the burden of all its effort is efficiency in the final product. Its work with cotton promises to do nothing less than to revolutionize the cotton industry. The special difficulty with the present Upland cotton is the shortness of the "staple" or fibre. This inch-long staple sells at present (1903) for eight to eight and one-quarter cents a pound, whereas the long staple of the Sea Island cotton sells for twenty-five to thirty cents per pound. The effort is to secure a longer staple for the Upland, either by crossing it with the Sea Island or by working with some foreign long-staple type. The Egyptian cotton has a long staple, and this is now being used as one of the foundation stocks. But the Egyptian cotton possesses faults along with its long staple. It will be the work of years' by means of careful selection, to augment or maintain the desirable qualities and to eliminate the undesirable qualities; when this is done, the cotton will no longer be the Egyptian, but practically a new creation, and this new creation should receive a new name in order to distinguish it from the inferior Egyptian from which it will have had its birth. Under the leadership of Mr. Webber, this new plant-bleeding enterprise (probably the largest in the world) is now extended to citrous fruits, apples, pineapples, oats, tobaccos and other crops; and there is every indication that its usefulness will expand greatly within the immediate future. Other institutions, and other divisions of the Department of Agriculture, are conducting similar work. Time is now on when every resourceful farmer must look to the improving of the intrinsic merits of his crops.

The modern methods of plant-bleeding demand, first, that the breeder shall familiarize himself thoroughly with the characteristics of the group of plants with which he is to work. He must have very specific and definite knowledge of what makes the plant valuable and what its shortcomings are. Then he must secure as starting-points plants that give promise in the desired direction. Thereafter his skill will be taxed in selecting along responsive lines, making accurate and significant statistical measures, in devising workable systems of testing. He must grow large numbers of plants, if he is working with farm crops, in order to multiply his chances of securing desirable variations and to minimize the errors.

A promising course of breeding is one that shall develop disease-resisting races within the variety. Considerable progress has already been made in this direction with cotton, oats and some other crops. Now and then a hill or a row or a variety of potato resists the blight. Why? May it not be used as a starting-point for the development of a blight-resistant strain? The development of disease-resisting and pest-resisting races is one of the most promising developments in the new plant pathology.

Nor are all these advances to be secured from seed selection alone. The cuttings and grafts of fruit plants perpetuate the parental characteristics with a good degree of surety. The time must soon come when it will not be sufficient to multiply the Bartlett pear from the Bartlett pear. We shall still further specialize our ideals and propagate from particular Bartlett pear trees that have made record performances. This subject is being tested in New York and elsewhere. It is one of the most important problems now before the nurseryman and orchardist.

All this plant breeding work is especially of a kind to demand governmental support. The progress of invention can be left to private initiative, because the person can patent his device and secure all the financial returns that it is worth. A variety cannot well be patented or controlled. This is particularly true of these great race improvements, in which no distinct and namable variety results; and these race improvements are the very ones that are most likely to be of greatest benefit to agriculture and therefore to the nation.

These methods and ideals may all be summed up as follows:

I. To determine on what the merit in any group of plants depends, and to find out what is needed to make the plants more efficient. What makes a potato "mealy"?

II. Securing a start in the desired direction by

(*a*) Choosing for seed-bearing any plants that are promising;

(*b*) Introducing prominent foundation-stock from other regions or other countries;

(*c*) Crossing for the purpose of injecting a new or better character into the strain.

III. Continued selection, careful testing and accurate statistical measurements and records to keep the progress true to line.

The first thing that strikes one in all this new work is its strong contrast with the old ideals. The "points" of the plants are those of "performance" and "efficiency." It brings into sharp relief the accustomed ideas as to what are the "good points" in any plant, illustrating the fact that these points are for the most part only fanciful, are founded on *a priori* judgments, and are more often correlated with mere "looks" than with efficiency. An excellent example may be taken from corn. In "scaling" any variety of corn, it is customary to assume that the perfect ear is one nearly or quite uniformly cylindrical throughout its length and having the tip and butt well covered with kernels. In fact, the old idea of a good variety of corn is one that bears such ears. Now this ideal is clearly one of perfection and completeness of mere form. We have no knowledge that such form has any correlation with productiveness, hardiness, drought-resisting qualities, protein or starch content—and yet these attributes are the ones that make corn worth growing at all. An illustration also may be taken from string beans. The ideal pod is considered to be one of which the tip-projection is very short and only slightly curved. This apparently is a question of comeliness, although a short tip may be associated in the popular mind with the absence of "string" in the pod; but we do not know that this character has any relation to the efficiency of the bean pod. We are now undergoing much the same challenging of ideas respecting the "points" of animals. These "points," by means of which the animals are "scored," are in large part merely arbitrary. Now, animals and plants are bred to the ideals expressed in these arbitrary points, by choosing for parents the individuals that score the highest. When it becomes necessary to recast our "scales of points," the whole course of evolution of domestic plants and animals is likely to be changed.

We are to breed not so much for merely new and striking characters that will enable us to name, describe and sell a "novelty," as to improve the performance along accustomed lines. We do not need new varieties of seedling potatoes so much as we need to improve, by means of selection, some of the varieties that we already possess. We are not to start with a variety, but with a plant. It is possible to secure a five per cent. increase in the efficiency of our field crops; this would mean the annual addition of hundreds of millions of dollars to the national gain.

The purpose, then, of our new plant-breeding is to produce plants that are more efficient for specific uses and specific regions. They are to be specially adapted. These efficiency-ideals are of six general categories:

1. Yield ideals.
2. Quality ideals.
3. Seasonal ideals.
4. Physical conformation ideals.
5. Regional adaptation ideals—as to climate, altitude, soil.
6. Resistant ideals—as to diseases and insects.

The main improvement and evolution of agriculture are going to come as the result of greater and better crop yield and greater and better animal production. It is not to come primarily from invention, good roads, rural telephone, legislation, discussion of economics. All these are merely aids. Increased crop and animal production are to come from two agencies: improvement in the care that they receive; improvement in the plants and animals themselves. In other words, the new agriculture is to be built upon the combined results of better cultivation and better breeding. So far as the new breeding is concerned, it is characterized by perfect definiteness of purpose and effort, the stripping away of all arbitrary and factitious standards, the absence of speculative theory and the insistence upon the great fact that every plant and animal has individuality.

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THE CURTIS STEAM TURBINE.

BY W. L. R. EMMET.

(Read April 2, 1903.)

The development which this paper describes is based upon the original theories and inventions of Mr. C. G. Curtis, of New York, whose ideas were first made the subject of patent application about 1895. Since that time these inventions have been the subject of experimental investigation at Schenectady, under the direction of Mr. Curtis and of the General Electric Company's engineers; the object of these experiments being to establish data and laws which would form a basis for the correct design of commercial apparatus. The difficulties of such an investigation are very great. All new facts must be established by the tests of different machines or parts which are difficult and expensive to produce. About two years ago